

Grant Number: NAG5-7071
Performance Period: 15 February 1998 to 14 February 2000
Grant Title: Small-Scale Polygons and the History of Ground Ice on Mars
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OVERVIEW:

The geologic character of the martian surface is strongly affected by the presence of subsurface water ice. On Mars, water is inferred to be abundant as near-surface ground ice at middle and high latitudes. The ice may be present as close as several tens of centimeters to a meter from the surface, at latitudes poleward of about $\sim 40^\circ$ [see Mellon and Jakosky, 1993; 1995]. One of the most ubiquitous geomorphic features in terrestrial permafrost are ice-wedge polygons, formed by repeated seasonal thermal-contraction cracking of ice-rich soils. On Mars, similarly small 10 to 100 meter-scale polygons have been and have been tentatively attributed to the product of ice-rich soil. These features have the potential to yield valuable information about the distribution of ground ice, the ground ice history, and the climate history. The most direct information is that the latitudinal distribution of polygons can indicate the latitudinal distribution of ground ice, if indeed they are related. We are examining the process of formation of thermal contraction polygons on Mars, determining the conditions required for their formation, characterizing their latitudinal distribution, expected size, and geomorphic signature, and applying these concepts to polygons observed on Mars.

RESULTS:

Finite Element Modeling (TECTON)

We have acquired a finite element model from Jay Melosh (called TECTON) which was developed for terrestrial and planetary rock and crustal deformation studies [Melosh and Raefsky 1980, 1981]. This model has previously been used successfully in planetary studies involving crater-profile relaxation on icy satellites [Hillgren and Melosh, 1989] and terrain softening of martian frozen regoliths [Jankowski and Squyres, 1993].

With the help of Collaborator Erik Asphaug (University of California, Santa Cruz), we have evaluated this model for use in martian permafrost polygon studies, by testing elastic and viscous limits with water-ice rheology against analytic solutions, and by performing simple simulations of pre-stressed crack opening under Mars-like temperature and anticipated stress conditions. However, TECTON is inherently a non-time-dependent model; the rheology and boundary conditions are fixed at initial values, and there is no provision in TECTON to include thermal contraction and expansion.

In thermal contraction polygons in permafrost, the driver is thermal contraction. Temperature oscillations also have an important influence on the rheology [e.g., Lachenbruch, 1963; Mellon, 1997], in particular the power law "viscosity" can change by orders of magnitude due to nominal changes in temperature that occur on Mars. To accommodate these influences, we have adapted TECTON to handle time-dependent changes in rheology which are defined by the subsurface temperature oscillations. We also included a component of isotropic thermal-contraction forcing.

This adaptation of TECTON to a time-dependent, temperature-dependent permafrost model is a major milestone in this research. This model can now be used to simulate a wide variety of situations and explore the conditions under which thermal contraction polygons may or may not form on Mars. Simulations can be varied by changing the input temperature or the boundary conditions. Changes in the rheology, such as between ice and frozen soil, are also relatively straightforward. Reaching this point opens a number of doors in this investigation.

Antarctic Field Data Collection and Terrestrial Analogs

We have been working with a group at the University of Washington (with Collaborators Bernard Hallet and Jaakko Putkonen, University of Washington, and Chris McKay, NASA Ames) on a study of periglacial geology in the Antarctic Dry Valleys, which includes monitoring sand-wedge polygons. During the last field season (Dec. 98 - Jan. 99) we instrumented several polygons in the Dry Valleys for subsurface temperature and crack strain. Data from these sensors are being collected continuously for two years (Jan. 99 - Jan. 01). The first year's data has been retrieved and is now being analyzed.

In addition to the analysis of Antarctic Dry Valley temperature and strain data, we have begun analysis of existing terrestrial permafrost temperature data (with Collaborator Jaakko Putkonen, University of Washington). Using the model of Mellon [1997] and the TECTON-based model described above, thermal stresses and polygon-crack strains can be calculated. Analysis of terrestrial permafrost data is extremely helpful in validating, calibrating, and tuning the Mars polygon models, as well as furthering our understanding of this geologic process on Earth.

Mars Climate Change Modeling

In Mellon [1997] the potential for the formation of thermal contraction cracks in martian permafrost was examined for the current martian climate. However, Mars undergoes significant variations in its orbit and climate. These variations are responsible for changes in ground ice stability mentioned above [Mellon and Jakosky, 1995] from ground ice being stable globally to being restricted to poleward of 60° to 70° latitude. The question of how such orbital changes effect the thermal contraction stress and the ability for cracks and polygons to form was investigated. The model of Mellon [1997], was used in conjunction with subsurface temperatures calculated from a standard thermal model using different orbital configurations. Results (presented at LPSC, Mellon [1999]) showed that at higher obliquity (about 45°), when ground ice is expected to be stable and present globally, thermal contraction stresses exceed tensile strengths globally, providing favorable conditions for polygons to form.

CONCLUSION:

This research has laid a foundation for continued study of permafrost polygons on Mars using the models and understanding discussed here. Further study of polygonal patterns on Mars is proceeding (under new funding) which is expected to reveal more results about the origin of observed martian polygons and what information they contain regarding the recent history of the martian climate and of water ice on Mars.

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